## DISCUSSION BEFORE THE INSTITUTION, 8TH NOVEMBER, 1951

**Sir Archibald Gill:** The cable was produced to a very stringent specification laid down by the Post Office Engineering Department, which, in particular, imposed tight limits on attenuation and variation of impedance throughout the frequency range up to 30 Mc/s. The manufacturers made experimental lengths which were joined up at the works and tested, and then they were cut and drawn into ducts in the streets and re-joined and re-tested to make quite sure that when this cable was put in its characteristics would not be affected by handling operations.

The fact that the cable could transmit frequencies very much in excess of those required for this immediate purpose helped the Post Office designers, since they were able to work well above the television signal frequencies and could use a band up to 3·88 Mc/s wide, which eased the problem of asymmetric-sideband transmission and avoided the quadrature distortion which otherwise they would have had to face.

At the same time there were many technical problems involved. There was, for instance, the question of equalization. The attenuation equalizers, in addition to correcting attenuation, introduced additional phase distortion, and a phase equalizer produced additional attenuation distortion, so that it must have been difficult to get all these factors correctly balanced.

That the authors have been able to do this without an overall correction is of great advantage, and makes for great flexibility in the set-up. During my Presidential Address last year my colleagues set up a circuit on this cable to transmit a television signal from Alexandra Palace to Birmingham and back to this building, and the result before and after transmission was displayed on cathode-ray tubes in the lecture theatre of The Institution. The transmission from the Museum Exchange to this building was over an ordinary telephone circuit which had been temporarily equalized for this purpose, and so the full definition possible with this system could not be shown. The pictures which have been shown are most remarkable and the photographs which showed enlarged details of the signal before and after transmission were so much alike that any difference between the two seemed imperceptible.

Before the cable was brought into use, the service to Sutton Coldfield had been carried between the Museum Exchange in London and Telephone House in Birmingham by a chain of radio links which have been described in a paper by Clayton* *et al.* That chain of radio links was produced very speedily by the contractors and was set up in rather a temporary form to meet the date of opening of the Sutton Coldfield station. In order to provide for transmission in the opposite direction, when required, all the intermediate stations were fitted with specially designed change-over switches. In its final condition the radio system will be capable of simultaneous two-way transmission. To enable it to be completed, the radio circuit was withdrawn from use and the cable put into service. As the authors have said, the cable with the associated equipment has turned out to be very reliable.

The work described in the paper was probably the most difficult of all, but many of the problems were not technical ones. From the map given in Fig. 5 it will be seen that there are between 40 and 50 intermediate repeater-stations on the route, and each of these had to be as nearly as possible at a 3-mile spacing. The difficulties of getting a piece of land just at the right point on a long route of that kind, often in built-up areas, have to be experienced to be believed. Moreover, with a 3-mile spacing one cannot depart very much from the 3 miles. If the spacing is 20 miles, then a mile either way does not matter, but in this case it had to be within 200 to 300 yd. There are powers given to certain public bodies to purchase land compulsorily, but in practice the process takes years to carry out. It is a great tribute to the persuasiveness of some of our engineers and members of the Ministry of Works that they acquired all these sites within a reasonable time and at not undue cost.

**Dr. A. R. A. Rendall:** When the paper dealing with the London–Birmingham radio-relay link* was read, I thought that the most important characteristic to which I should draw attention was its reliability. The service is now carried by this cable, and this has been done so well and so reliably that to make any comparison on the basis of reliability with its predecessor would serve no useful purpose.

What strikes me most forcibly is what I would call the technical elegance and simplicity of this method of conveying television signals. Although there must have been many severe technical problems, I feel that there is no fundamental technical difficulty involved, such as results from transmitting a video signal in a frequency band on the cable which overlaps with the actual video-frequency band. In that case one is confronted with very severe difficulties with regard to harmonic production which makes the problem of repeater design much more difficult. I wonder whether it would not prove advantageous to transmit a video signal in a system similar to that which the authors have described on a $\frac{3}{8}$-in coaxial cable with repeaters spaced at 3-mile intervals.

The London–Birmingham cable itself has two 1-in tubes. I do not know that anyone would suggest, at least in the present era of economy, that such a cable should be further extended, but this suggestion of doubling the number of repeaters is perhaps not so impossible as it may seem at first sight. If only the repeater stations could be made really simple, one could widen the frequency band, simplify the repeaters, and introduce circuit simplification to such an extent that the total number of valves used would probably be not much more than in the system at present contemplated for $\frac{3}{8}$-in coaxial cables. The repeater expense itself would be increased, but the expense of terminal apparatus would be very much reduced, and in addition it might be possible to share the coaxial channel between communication and television services. We are, of course, very keen on this, since it might reduce the cost of the channel to the television service.

I should like to commend one part of the paper to the exponents of the waveform method of lining-up and equalizing a television system. In Section 3 the authors have emphasized that, where there is a number of links in a chain, the only practical way of doing the job is to decide on a given frequency band and fully equalize in that frequency band as regards both attenuation and phase. It is conceivable that, if you multiply the number of links in that chain, it may be advisable to add some sort of overall correction, which might take the form of pulse correction.

Finally, I should like to say that the precise equalization described as regards both attenuation and delay distortion has been well maintained over the whole period for which the cable has been in operation. We have made, in co-operation with the Post Office, a number of very careful tests, and I can assert that, after rather more than a year, these results have been maintained.

**Dr. R. L. Smith-Rose:** In reading this paper I was led to wonder exactly what was the target specification which the Post Office were aiming at in developing this cable. Having referred to the paper by Clayton *et al.*, already mentioned in this dis-

* Paper by R. J. CLAYTON, D. C. ESPLEY, G. W. S. GRIFFITH and J. M. C. PINKHAM (see 1951, 98, Part I, p. 204).

* *Op. cit.*

cussion, I assume that the specification for the radio link was in general the same as for the cable link, because surely it should be impossible for the B.B.C., as users of the link between London and Birmingham, to discover whether the Post Office are using the cable or the radio link.

In fairness to the Post Office, I ought to say that I did in fact find that such characteristics as I could identify in the radio-link specification appeared to have been met very well indeed in the performance of this particular cable. I had, however, owing to this lack of a specification, to sort out my ideas as to the time-scale and what these various time-delays and attenuations meant in relation to the desirable objective in view. I know, for example, that the duration of the length of one scanning line with our television system is some 85 microsec, and therefore a phase delay of a few hundredths of a microsecond represents an extremely small fraction of a line.

In this matter I am impressed by the precision with which phase delay and attenuation can now be measured. Some of these curves have a maximum on the ordinate scale of 0·1 microsec and attenuation characteristics of 0·1 db. The fact that we are now concerned with attenuations of a small fraction of a decibel made me wonder whether the decibel is a suitable unit, and whether we do not need a centibel or even a millibel.

As I understand it, one of the objectives of having both a radio link and a cable link between London and Birmingham is to enable the Post Office and the B.B.C. to gain some experience on the relative merits of the two systems. Having had these two papers, on the radio and cable links respectively, I trust that we may look forward to having a third paper presented to us which will outline the experience obtained by the users and suppliers of these links, on their performance, which is a very vital matter in the development of the means of relaying television programmes in the future. As engineers, I think that we would hope that this future paper will pay some attention to the economic aspects of the whole system as well as to the technical aspects.

**Mr. H. Faulkner:** I agree with Sir Archibald Gill that the opening of this cable marks an epoch in our communications system. It is the first long-distance cable to carry a television programme in Europe, and I think that it is the only coaxial cable of 1 in diameter to be put into commercial use on land in the world.

As Dr. Rendall has suggested, the circuits in this system are essentially simple, but that does not mean that they have not involved a very large amount of detailed work and investigation, owing to the special nature of the requirements. The problem of obtaining a constant overall amplification of about 550 db over a 3-Mc/s band is a very difficult one, and the necessity for differential phase-equalization and the provision of the necessary supervisory circuits to minimize the risk of breakdown had also to be faced. I think that the demonstration which was given of the automatic changing-over of the standby plant on the occurrence of a fault was very convincing and showed clearly what is entailed by the latter consideration. There was also the problem of feeding the power for the valves over the cable to reduce to a minimum the points at which a power supply was necessary, and I think that the authors are to be congratulated on the way in which all these problems were solved.

When reading this paper, I was driven to consider the differences in requirements between multi-channel telephony and television transmission, from both a technical and an economic point of view. On the technical side, for television, careful equalization of phase over the frequency band is necessary. That is not so for multi-channel telephony, where one has a number of discrete channels and differential delay creates no problem. On the other hand, multi-channel telephony demands a much higher degree of linearity of response on the part of the amplifier to avoid intermodulation of the channels. The two cases therefore have different technical requirements.

There is also a difference between multi-channel telephony and television from the point of view of economics. With the present system of multi-channel telephony a big proportion of the cost is in the terminal apparatus, and it might pay to use a bigger cable if the requisite savings could be made in its cost. In television, on the other hand, the terminal apparatus is comparatively simple and there is no margin for economy. It is therefore necessary to consider whether the present standard size of cable represents the optimum size from an economic point of view for either or both of these uses.

Dr. Rendall's suggestion that we might have a multi-channel telephony system in addition to television is a very good one, and I am sure it will be borne in mind, but it is one which requires considerable development. There is also a possible need for a system which would be suitable alternatively for both television and multi-channel telephony. For this to be possible it would be necessary to improve the linearity of response, and perhaps the authors will say what further development would be necessary to enable this to be done. I suggest this because, if an international interchange of programme is to be possible in the future, and with the plans for coaxial cables to interconnect the capitals of Europe, it might be feasible to make use of the differences in the requirements of telephony and television in time, switching the circuits over from telephone to television for occasional programme purposes.

**Mr. A. W. Montgomery:** Television is in its early stages as yet, and we still do not know what tricks can be played on the eye to lessen the cost of providing acceptable entertainment. The history of sound broadcasting is being repeated. We marvelled initially at the transmission by radio of any standard of music. Then, by degrees, as more was learnt and the tricks which could be played on the ear were found, the bandwidth requirements went up to 5 kc/s, then to 8 kc/s, and, as still more became known, up to 15 kc/s. But costs and results then indicated that the improvement given by the increase from 8 to 15 kc/s was rarely justified, and we are back now in most cases to 8 kc/s or less. Work on television goes on in several countries, including Great Britain, to determine the minimum requirements which must be met in order that the brain will get the required sensation of moving pictures transmitted from a distance, and the results of this work already seem to be showing that much apparent intelligence is unnecessarily transmitted at present. A reduction in bandwidth requirement therefore seems to be possible in the future. The country which goes farthest ahead with the study of television and the eye will, in the end. have the first economic television system. At present, in setting requirements we rely on empirical results and methods of measurement based on them. Interpretation of results depends on experience, the particular methods of measurement and the chosen signals (see, for example, the authors' comments on measuring differential delay).

But even when we discuss bandwidth, we have to define what we mean. What variations over the band are to be assumed? No cable or radio link for television transmission should have a sharp cut-off, and the attenuation characteristic, for example, may be flat up to 3 Mc/s and then tail off in some way which call be important. So that the value of 3 Mc/s in the paper may well be called 5 Mc/s or more in other countries. Again, if the "tail" must be controlled, as seems to be desirable, the linking of channels in tandem will also add to the difficulties of defining and specifying. These are things which will be settled in the future at a date which will be determined by the work on the eye, television technique and economics.

Finally, I would add that it grieves me as a telephone engineer to realize that all this beautiful bandwidth so much required for badly needed telephone channels is being used for television.

**Mr. L. I. Farren:** My feeling on reading the paper was that a number of comparisons had been made with the existing American system, and they were generally adverse. I feel that some defence should be made in favour of the Americans. The American system transmits a vision band of 2·8 Mc/s with a line frequency band extending up to 3·1 Mc/s, while the system described in the paper transmits 3 Mc/s vision on a line frequency band extending up to 7 Mc/s. The comparison is obvious. As we all know, the Americans have a strong objection on their broadcasting and television to what they call "unused programme time." Our mathematicians can show us that time and frequency are inverse quantities; I think that the Americans would object just as strongly to unused frequency band.

I agree with other speakers, however, that for simplicity and elegance there are many features about the system described which are most attractive.

In Section 5.2, emphasis is laid on the fact that, because the vestigial-sideband filter has a very gradual cut-off slope, namely 0·014 db/kc/s, a crystal oscillator for the system does not need temperature control, and its stability is not important. I should have thought that what really matters is the stability of the filter. The filter contains coils and condensers which are always inherently less stable than a crystal oscillator. If, in fact, the cut-off frequency of the filter changes by 0·1%, there will be a change of 0·1 db at the low-frequency end of the vision signal, and to achieve this stability of cut-off frequency is fairly difficult using conductors and capacitors. In the American system, which has a vestigial band cutting-off eight times as fast, the requirements are eight times as hard, and 0·1% change in cut-off gives nearly 1 db rise or fall in the vision frequency characteristic, which is very large.

Much has been said and published about time equalization, and we all know that Dr. Espley has propounded the theme and given some elegant solutions. Will the authors say whether time equalization was ever considered in this system and ever tried at any stage?

In connection with the measurement of group delay, I have recently seen results of measurements with a 20-kc/s envelope signal as against 100 kc/s, and it is interesting to study the result. The result obtained is what would be expected, in that the nature of the characteristic is finer structured, but the additional information obtained from it is not really needed.

From the results shown, the effects of irregularities of impedance in the cable are obviously negligible. I should like to know whether, if the frequency band were extended to 15 or 30 Mc/s, as is suggested, that would still be the case, or whether troubles would arise at these higher frequencies.